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1987 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

September 1988

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COORDINATING RESEARCH COUNCIL, INC.
219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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1987 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

(CRC PROJECT No. CM-124-87)

Prepared by the

CRC Octane Technology and Test Procedures Group

September 1988

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

ABSTRACT

An octane number requirement rating workshop was sponsored by Coordinating Research Council, Inc. May 19-22, 1987, in Phoenix, Arizona. The objective of the workshop was to improve the application of the CRC E-15 Technique for Determination of Octane Number Requirements of Light-Duty Vehicles to provide consistent results with vehicles equipped with knock sensors, turbochargers, and various transmission configurations. Training was accomplished through seminars and demonstrations, and was verified with actual track testing using the E-15 rating technique and appropriate equipment. (JTS)

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I. INTRODUCTION

An octane number requirement rating workshop was sponsored by the Coordinating Research Council, Inc. (CRC) May 19-22, 1987, in Phoenix, Arizona. The objective of the workshop was to improve the application of the CRC E-15 Technique for Determination of Octane Number Requirements of Light-Duty Vehicles to provide consistent results with vehicles equipped with knock sensors, turbochargers, and various transmission configurations. The workshop was conducted in response to interest expressed. Although initial plans called for approximately twenty-five attendees, forty-one technicians, raters, and engineers actually attended. Attendees of the workshop are listed in Appendix A. Training was accomplished through seminars and demonstrations, and was verified with actual track testing using the E-15 rating technique and appropriate equipment.

II. TEST VEHICLES

Nine 1987 model vehicles were available for track testing as follows:

Make/Model	Displacement, liters	Fuel System	Knock Sensor	Transmission
Buick Century	2.8	Port-Injected	Yes	Automatic 3-speed lockup
Buick LeSabre	3.8	Port-Injected	Yes	Automatic 4-speed lockup
Chrysler LeBaron	2.2	Port-Injected	Yes	Automatic 3-speed
Dodge 600	2.5	Throttle-Body-Injected	No	Automatic 3-speed lockup
Ford Tempo	2.3	Throttle-Body-Injected	No	Automatic 3-speed
Ford Taurus	3.0	Port-Injected	Yes	Automatic 4-speed lockup
Nissan Maxima	3.0	Port-Injected	No	Automatic 4-speed lockup
Plymouth Voyager	3.0	Port-Injected	No	Automatic 3-speed
Pontiac 6000	2.5	Throttle-body-Injected	No	Automatic 3-speed lockup

Four of the nine vehicles were equipped with knock-sensor devices, and one of the vehicles was turbocharged. All of the vehicles were fuel-injected and had automatic transmissions.

III. TEST FUELS

The test fuels used during the workshop were the 1985/1986 CRC Full-Boiling Range Unleaded (FBRU) fuels. The fuels were prepared from three base blends (RMFD-356-85/86, RMFD-357-85/86, and RMFD-358-85/86) in one octane number increments from 78 to 103 RON.

The base blends were prepared from normal refinery components. Inspection data furnished by the supplier are given in Table I. The composition and average laboratory octane data for the 1985/1986 FBRU reference fuel series are presented in Table II.

IV. TEST PROGRAM

The workshop was conducted May 19-22, 1987, at the Firebird International Raceway located on the outskirts of Phoenix, Arizona. The timing of the workshop was planned such that the results of it could be used for the 1987 CRC Octane Number Requirement Survey.

The workshop incorporated classroom-type discussion, alternated with vehicle octane requirement tests on the track by individual teams. Participant discussions during crew operations, between vehicles, and in group sessions generated suggestions for modifying the current test technique and data sheet. Major problems which the raters had experienced with the E-15 Technique were:

- Definition of borderline (along with above and below borderline) knock for knock sensor-equipped vehicles;
- Maximum-throttle accelerations for turbocharged cars (vacuum/pressure versus speed profiles); and
- Converter lockup clutches.

Representatives from several of the automobile manufacturers were available to answer individual questions about their respective knock-sensor systems and converter clutch transmissions.

Since the purpose of the workshop was to be an educational experience rather than a source of octane requirement data, emphasis was placed upon exchange of information as opposed to data collection and analysis. The intent of the workshop was not to "rate the raters," but to reduce the laboratory-to-laboratory variations in the application of the E-15 Technique. Raters from different companies were assigned to work together on a rotating basis in an effort to improve and promote communication among

raters on the various ways in which different laboratories employ the E-15 Technique. The consensus of the workshop attendees was that this was an extremely successful way to learn better and more consistent methods of utilizing the E-15.

V. ANALYSIS OF DATA

This report contains no analysis of the data submitted during the workshop, because the data do not offer any information about the operations of the workshop. The workshop was designed to improve the application of the E-15 Technique, and its success was the clarification of the technique among the participants in the workshop. In addition, the workshop participants recommended clarifications in the actual documents defining the E-15 Technique.

The individual data sheets were reviewed on-site shortly after the completion of the rating of a vehicle. This review was primarily concerned with the proper completion of the rating form; however, it was noted if the rating appeared to be inconsistent with other ratings. Based upon this information, the individual rater was approached, and any necessary corrective actions were discussed with him as soon as possible.

The complete set of data for all of the vehicles has been reviewed and found to be of little value for evaluating the raters. This is not surprising, since the program was not designed for this purpose and was not expected to provide this type of information. The major difficulty in making any evaluation of individual raters was due to operational conditions which could be expected to cause wide variations in the individual vehicle ratings. The vehicles were also being continuously rated, which normally causes a decrease in the requirement due to severe service. These effects could not be separated from the rater effects; thus, evaluation was not possible.

VI. RECOMMENDATIONS FOR IMPROVING E-15 TECHNIQUE

Along with various minor modifications intended to clarify the procedure, several recommendations were made to simplify and improve the E-15 technique. These recommendations were transmitted to the Steering Panel of the CRC Octane Number Requirement Survey Group for their action. The Steering Panel incorporated the recommendations into the E-15-87 Technique which was subsequently distributed to the Group members for their use in the 1987 CRC Octane Number Requirement Survey. The revised E-15-87 Technique is included as Appendix B of this report, and the recommended changes are indicated by italics. The changes do not substantially alter the substance nor the scope of the E-15 Technique, but they do serve to clarify instructions to raters and update the rating technique. Significant modifications to the Technique were concerned with the establishment of automatic transmission characteristics and the part-throttle accelerations. The procedure for setting-up fuel-injected

vehicles for reference fuel testing was also rewritten. Other changes were made either for safety considerations or were editorial in nature. The major modifications to the Technique are as follows:

Spark Knock is defined as it has been in the past. The definition is clarified to include knock occurring when going from road load to other operating conditions (e.g., tip-in, etc.).

Establishment of Automatic Transmission Characteristics has been expanded to include instructions for operation of transmissions equipped with electronic overdrive or power/normal selection.

Part-Throttle Acceleration instructions have been clarified for automatic transmissions. For automatic transmissions, the two highest gears are to be tested, with the converter clutch both engaged and disengaged. Use of vehicle brakes during part-throttle accelerations should be avoided.

Vehicle Rating Procedure initial accelerations should all be started from minimum obtainable gear/converter clutch combination at constant level road-load conditions.

The Procedure for Setting Up Vehicles with Fuel Injection has been completely rewritten into a generic procedure applicable to all fuel-injected vehicles.

Recommended modifications to the CRC octane number requirement rating data form DFMF-11-87 are shown in Appendix C. These recommended changes are primarily intended to clarify and simplify the rating form.

VII. RECOMMENDATIONS FOR FUTURE RATING WORKSHOPS

The consensus of the attendees was that, due to its value, an octane number requirement rating workshop should be conducted at least every two years. It was recommended that an abbreviated set of reference fuels be used in the next workshop. The primary benefit derived from the workshops is gaining experience with the various transmission characteristics, knock sensors, etc., rather than actually defining the octane requirements of the vehicles; therefore, a full complement of reference fuels is not necessary. Because of its success, there was a great deal of support for comprising rating teams at future workshops with raters from different companies. An additional suggestion was to include chassis dynamometer work in the next workshop, since so many laboratories rate on chassis dynamometers.

TABLES

TABLE I

SUPPLIERS' FUEL INSPECTIONS

1985/1986 FBRU FUELS

	Low-Octane Base Blend RMFD 356-85/86	Intermediate-Octane Base Blend RMFD 357-85/86	High-Octane Base Blend RMFD 358-85/86
Laboratory Inspection			
Distillation, °F			
IBP	91	93	94
10% Evap.	120	124	126
30% Evap.	153	154	186
50% Evap.	195	198	238
70% Evap.	230	251	255
90% Evap.	313	337	291
End Point	388	399	377
Gravity, °API	67.0	62.8	52.3
RVP, psi	8.6	7.6	8.1
Lead, g/gal	<0.03	<0.03	<0.03
Oxidation Stability, hr.	>24	>24	>24
Hydrocarbon Type, Vol. %			
Aromatics	22	27	55
Olefins	5	10	1
Saturates	73	63	44
Research Octane Number	76.6	90.3	103.5
Motor Octane Number	72.7	82.0	92.3
Sensitivity	3.8	8.3	11.2

TABLE II

OCTANE NUMBERS AND COMPOSITIONS FOR 1985/1986 FBRU FUELS

RON	Blending Data Composition, Volume Percent RMFD 356-85/86	RMFD 357-85/86	RMFD 358-85/86	MON	Sensitivities 1985
78	92	8	--	73.8	4.2
80	78	22	--	75.4	4.6
82	64	36	--	76.9	5.1
84	49	51	--	78.4	5.6
85	42	58	--	79.0	6.0
86	34	66	--	79.6	6.4
87	26	74	--	80.3	6.7
88	18	82	--	80.8	7.2
89	11	89	--	81.3	7.7
90	3	97	--	81.9	8.1
91	--	95	5	82.5	8.5
92	--	88	12	83.0	9.0
93	--	81	19	83.6	9.4
94	--	73	27	84.3	9.7
95	--	65	35	85.1	9.9
96	--	57	43	85.7	10.3
97	--	49	51	86.5	10.5
98	--	41	59	87.2	10.8
99	--	33	67	88.1	10.9
100	--	24	76	89.0	11.0
101	--	16	84	89.9	11.1
102	--	9	91	90.8	11.2
103	--	0	100	92.2	10.8

APPENDIX A

ATTENDEES OF THE
1987 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

PARTICIPANTS IN THE 1987 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

NAME	COMPANY AFFILIATION
John Baker	Shell Development Company
Jack Benson	General Motors Research Laboratories
Bill Biller	Consultant
Giles Bostick	Ashland Petroleum Company
Paul Brigandi	Mobil Research & Development Corporation
Greg Brooks	Unocal Corporation
Jim Callison	Amoco Oil Company
Dick Dizak	Consultant
Donald Dodd	Phillips Petroleum Company
Dave Duckert	Esso Petroleum Canada
Jim Duffy	Exxon Research & Engineering Company
Dennis Dunning	AutoResearch Laboratories, Inc.
Leo Ensz	Shell Development Company
Beth Evans	Coordinating Research Council, Inc.
Larry Freedman	Mobil Oil Corporation
Don Gibbs	Mobil Research & Development Corporation
John Graham	Chevron Research Company
Kurt Groll	Texaco Inc.
Bruce Henderson	Amoco Oil Company
Steve Hill	Amoco Oil Company
Donna Hoel	Exxon Research & Engineering Company
Bill Honchar	Petro-Canada Products
Hiroki Kawajiri	Nissan Research & Development
Toshio Kobayashi	Nissan Research & Development
John Krylowski	Exxon Research & Engineering Company
Tom Kueny	Chrysler Arizona Proving Grounds
John McDougal	McDougal Engineering
Art Montenegro	Chevron Research Company
John Parker	Texaco Inc.
Stan Pilling	Sun Refining & Marketing Company
Doug Rathe	Shell Development Company
Val Rodrigues	Chevron Research Company
Jack Sidor	Sohio Oil Company
Clint Smith	Esso Petroleum Canada
Don Stafford	Unocal Corporation
Bill Steckle	Petro-Canada Products
Masahiro Toi	Nissan Research & Development
Jim Uihlein	Sohio Oil Company
Ed Willis	Sun Refining & Marketing Company
Jim Wooten	Phillips Petroleum Company
Tim Wusz	Unocal Corporation

APPENDIX B

REVISED TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS (CRC E-15-87 TECHNIQUE)

TECHNIQUE FOR DETERMINATION
OF OCTANE NUMBER REQUIREMENTS
OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-87)

June 1987

NOTE: Recommended changes resulting from the 1987 CRC Octane Rating Workshop are indicated by italics.

TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-87 - Including Annex A)

A. GENERAL

The technique provides for the determination of maximum octane number requirements (and minimum octane number requirements for vehicles equipped with knock sensors), whether at maximum-throttle or part-throttle, of a vehicle in terms of borderline spark knock on two series of full-boiling range reference fuels as well as on primary reference fuels. If the maximum requirement is at maximum-throttle, then part-throttle requirements are investigated with only FBRU fuels of up to, and including, four octane numbers lower than the maximum requirement.

Knock intensity on tank fuel will be measured.

B. DEFINITION OF TERMS

The following definitions of knock, approved by the CLR and CFR Committees on June 8, 1954, have been rephrased for clarification and adaptability to current technology by the Survey Steering Panel.

1. Spark Knock:

Spark knock is the noise associated with the autoignition* of a portion of the fuel-air mixture ahead of the advancing flame front. It is recurrent and repeatable in terms of audibility and fuel octane quality. *This includes knock occurring when going from road load to other operating conditions (e.g., tip-in, etc.).*

2. Knock Intensity

a. Borderline Knock

This means spark knock of lowest audible intensity of at least three (3) pings, and over a range of engine speed of at least 50 rpm, all being repeatable during subsequent accelerations.

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* Autoignition: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel-air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for autoignition.

b. No Knock

This means either no audible knock or knock less than borderline intensity.

c. Above Borderline Knock

This means spark knock of greater than borderline intensity.

3. Octane Number Requirements

a. Maximum Requirement

This is equivalent to the octane number of the highest reference fuel giving borderline knock as previously defined (the next higher fuel gives no knock). If the knock intensity with the highest fuel giving knock is above borderline, the maximum requirement shall be equivalent to the mid-point between the octane number of the fuel giving knock and that of the next higher fuel which gives no knock.

b. Minimum Requirement (for vehicles with knock sensors)

This is equivalent to the octane number of the lowest reference fuel giving borderline knock (the next lower fuel will give above borderline knock). If the knock intensity with the lowest fuel giving knock is above borderline and the next highest fuel is no knock, then the minimum requirement is the mid-point between the two.

4. Definition of Accelerations

Accelerations are made at maximum-throttle and part-throttle conditions which are defined below:

a. Maximum-Throttle

The throttle is depressed and held at either full-throttle or the widest throttle position that does not cause the transmission to downshift (detent) throughout the acceleration in each of the required test gears listed in D.3.d.(1)(a). The detent manifold vacuum/pressure obtainable on a given model is determined by the transmission characteristics. For manual transmissions, the throttle is depressed fully throughout the acceleration.

b. Part-Throttle

The throttle is depressed and regulated throughout the acceleration to maintain a desired, constant critical manifold vacuum/pressure as defined in D.3.d.(1)(d).

C. VEHICLE PREPARATION

The following vehicle preparation steps should be completed before any octane tests are run. Detailed procedures for each adjustment can be found in the manufacturers' shop manuals.

1. Record vehicle identification number and emission control type, Federal, Altitude, California, or Fifty-State. Fill in headings on both sheets of data form DFMF-11-87. Ford emission calibration numbers are to be recorded.

2. Inspect all vacuum lines and air pump hoses for appropriate connections. Also, check to see if PCV valve, spark advance vacuum delay controls, EGR valve, knock sensors, and heated inlet air mechanism are functioning. Engine must be warmed up for these checks.

3. Check engine idle speed and observe anti-dieseling solenoid operation. Adjust to manufacturers' recommended specifications as specified on the under-hood decal.

4. Observe and record basic spark timing at recommended engine speed. Adjust to manufacturers' recommended setting as specified on the under-hood decal.

5. Crankcase oil, radiator coolant, automatic transmission fluid, and battery fluid levels shall be maintained as recommended by the manufacturer.

6. A calibrated tachometer graduated in 100 rpm (or smaller) increments and capable of indicating engine speed from 0-5000 rpm shall be installed on the vehicle.

7. One calibrated vacuum gage, graduated in one-half inch of mercury (or smaller) increments and capable of indicating vacuum from 0-24 inches of mercury (0-81 kPa) shall be connected to the intake manifold. For vehicles with turbochargers, a compound vacuum/pressure gage should be used; the pressure side of the gage should be capable of indicating pressures up to 15 psig (103 kPa).

8. An auxiliary fuel system shall be provided to supply test fuels to the engine. Caution shall be taken to avoid placing auxiliary fuel lines in locations which promote vapor lock. If vehicles with carbureted engines have tank return fuel lines, this return line should be blocked off. Disconnect fuel tank vent line at evaporation control system canister. Instructions for the auxiliary fuel system used with fuel injection are given in Annex A.

9. For vehicles with owner questionnaire completed, a sample of the tank gasoline shall be withdrawn for determination of Research and Motor method octane number ratings. If insufficient fuel is available, omit this step and obtain tank fuel observations as described in Item D.3.d.(2).

D. TEST PROCEDURE

1. Engine Warm-Up

a. To stabilize engine temperatures, a minimum of ten miles of warm-up is required. The test vehicle should be operated at 55 mph (88 kph) in top gear with a minimum of full-throttle operation.

b. During the warm-up period, the general mechanical condition of the vehicle should be checked to insure satisfactory and safe operation during test work.

2. Fuel Changeover

To eliminate contamination of the new fuel with residual amounts of the previous fuel, fuel-injected systems should be flushed once with new fuel and carburetted systems should be flushed twice. Fuel handling procedures for vehicles equipped with fuel injection systems are explained in Annex A.

After fuel changeover, make one maximum-throttle acceleration before beginning Vehicle Rating Procedure.

3. Details of Observations

a. Operating Conditions

All octane number requirements will be determined under level road acceleration conditions.

Tests will be conducted on moderately dry days, preferably at ambient temperatures between 60°F (15.5°C) and 90°F (32.2°C). Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F (21°C) air temperature and 50 grains of water per pound (7.14 gm/kg) of dry air whenever possible.

Air-conditioned vehicles will be tested with air conditioner turned ON. (Normal setting, minimum temperature, low fan.) Air conditioner will be ON at all times.

b. Order of Fuel Testing

1) Tank 3) FBRU

2) FBRSU 4) Primary

c. Determination of Knock Intensity

Maximum octane requirements will be established by evaluating the occurrence of knock in terms of knock intensity: "N" for none, "B" for borderline, and "A" for above borderline. Establishment of representative knock intensity for a given fuel will be accomplished with a maximum of three (3) rated accelerations. Coastdown time between the end of one acceleration and the beginning of the next should be approximately twenty (20) seconds. As defined below, the first two duplicating accelerations are sufficient with "N" and "B" intensity.

Acceleration Number			Representative Rating
1	2	3	
N	N	-	N
N	B	N	N
N	B	B	B
B	N	B	B
B	B	-	B
B	A	-	A
A	-	-	A

All subsequent accelerations will normally be discontinued when "A" knock intensity is experienced, and testing continued with a higher octane number fuel in that series. An exception will be made if "A" knock is experienced on the highest octane fuel which knocks in the engine. In this case, it may be necessary to run additional accelerations to determine the speed of maximum knock intensity. If "A" knock is experienced at initiation of acceleration, as limited by transmission characteristics, this speed will be considered the speed of maximum knock. Otherwise, the midpoint between knock-in and knock-out will be considered the speed of maximum knock. When establishing knock-in and knock-out, back off on the throttle between points to eliminate "A" knock.

Minimum octane number requirements for vehicles equipped with knock sensors will be established in a similar manner except that when "A" knock intensity is encountered, subsequent accelerations will be made with a given fuel until duplicate "A" ratings are obtained over a measurable range of engine speeds as indicated below:

Acceleration Number			Representative Rating
1	2	3	
B	A	B	B
B	A	A	A
A	A	-	A
A	B	B	B

d. Determination of Octane Requirements

Tests should be run to 70 mph (113 kph). If required to terminate at lower speed, termination speed should be noted on data sheet.

(1) Vehicle Operating Procedure

(a) Establishment of Automatic Transmission Characteristics

Determine the minimum attainable road speed, and obtain the transmission downshift characteristics of engine rpm and manifold vacuum/pressure from minimum speed at 25, 35, 45, 55, and 65 mph (40, 56, 72, 88 and 104 kph) as applicable (as obtainable in each gear), by movement of the throttle through the detent, i.e., downshift, throttle position. These characteristics are to be determined for each of the gears specified in the table below. For transmissions with converter clutches, determine the minimum road speed for clutch application. At this initial speed and at 10 mph (16 kph), increments up to about 60 mph (97 kph) determine minimum vacuums (pressures) for application. Record all road speed/engine rpm/vacuum or pressure measurements from above on data sheet.

Do not use brakes, turn signals or hazard flashers during accelerations as these may affect electronic engine controls.

The selection of required test gears, and test gear/converter clutch combinations (if applicable) for various types of transmissions are shown in Table T-I. Transmissions not explicitly described should be tested in a manner as similar as possible to those listed. Automatic transmission vehicles should be tested with the gear selector in D or O; *top gear should not be locked out. Transmissions equipped with electronic overdrive should be operated in overdrive. Transmissions equipped with power/normal selection should be operated in the normal position.*

TABLE T-I

TRANSMISSION GEAR SELECTION

AUTOMATICS

Place the selector in "D" or "O" and check for critical condition.

Type	Gears to be Tested
GM 4-speed	4th gear, converter clutch engaged 3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
GM 3-speed/ *Chrysler 3-speed with converter clutch*	3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
Ford Front-Wheel Drive: 4-speed overdrive	4th gear, converter clutch engaged 4th gear, converter clutch disengaged *3rd gear, converter clutch engaged, if applicable* *3rd gear, converter clutch disengaged* 2nd gear
Ford Rear-Wheel Drive: 4-speed overdrive	*4th gear, converter clutch engaged, if applicable* *4th gear, converter clutch disengaged* *3rd gear, converter clutch engaged, if applicable* *3rd gear, converter clutch disengaged* 2nd gear
Other 3-speed	3rd gear 2nd gear

MANUALS

5-speed	4th and 3rd gears
4-speed	4th and 3rd gears
3-speed	3rd and 2nd gears

(b) Maximum-Throttle Accelerations - Automatic Transmissions

For maximum-throttle accelerations in each of the gears and gear/converter clutch combinations specified above, accelerate at the detent/application condition according to the speed versus vacuum/pressure profiles determined in (a) from the minimum obtainable speed up to *70* mph (*113* kph). If the transmission downshifts, abort and start the acceleration again. Start with the highest gear or gear/clutch combination and proceed in descending order.

(c) Maximum-Throttle Accelerations - Manual Transmissions

Select the highest gear as specified in the table above. Start at the lowest speed from which the vehicle will accelerate smoothly or *25* mph (*40* kph), whichever is higher, and depress the throttle full throughout the acceleration up to *70* mph (*113* kph).

Select the next lower gear specified in the table above and accelerate at full throttle from the minimum speed from which the vehicle will accelerate smoothly up to *70* mph (*113* kph).

(d) Part-Throttle Accelerations for Both Automatic and Manual Transmissions

Select the highest gear as specified in Table T-1 for manual transmissions. Select the two highest gears as specified in Table T-1 for automatic transmissions. For example, on a four-speed automatic transmission, check both fourth locked and unlocked and third locked and unlocked; on a three-speed automatic transmission, check third locked and unlocked and second. For automatic transmissions with converter clutches use the highest gear up to the minimum vehicle speed at which the converter clutch will engage, and the highest gear/converter clutch combination above this minimum speed, to obtain the critical part-throttle vacuum or pressure. To obtain the critical part-throttle vacuum/pressure, first operate at constant speed road load, at 25, 35, 45, 55, *and 65* mph (40, 56, 72, 88, *and 105* kph) incremental speeds if obtainable in the specified gear. At each speed, move the throttle in *approximately* 3 seconds from the road-load vacuum to the positions described below for naturally aspirated and turbocharged engines:

1. for naturally aspirated vehicles, one inch Hg (3.4 kPa) above:

    a. full-throttle vacuum for manual transmissions;

    b. detent vacuum for automatic transmissions without converter clutches;

    c. the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

2. for turbocharged vehicles, one psi (3.4 kPa) below:

    a. full-throttle maximum boost for manual transmissions;

    b. maximum boost at detent for automatic transmissions without converter clutches;

    c. maximum boost or 0.5 psig (1.7 kPa) above the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

Use of vehicle brakes should be avoided.

If knocking occurs within any of the vacuum/pressure ranges, establish the manifold vacuum/pressure which gives maximum knock intensity on each fuel series. This is the critical vacuum/pressure to be used for all subsequent constant-vacuum/pressure part-throttle accelerations from the minimum obtainable speed in the test gear to 70 mph (113 kph). or until the vehicle ceases to accelerate. This critical vacuum/pressure should be determined for each reference fuel series.

(2) Tank Fuel Observations

Investigate for maximum-throttle and part-throttle knock as detailed in Item 3d(1). Define maximum knock intensity as per Item 3c. Record maximum knock intensity, speed of maximum knock intensity, and manifold vacuum/pressure at each operating condition.

(3) Vehicle Rating Procedure

All initial accelerations should be started from minimum obtainable gear/converter clutch combination at constant level road-load conditions. Knock rating should be performed while in a normal upright seated position with floor mats in place.

Step 1 - After Tank Fuel Observations, use a fuel estimated to give borderline knock in a given fuel series and investigate for incidence of knock under conditions as described in D.3.d.(1)(b) above, and D.3.d.(1)(c) above, whichever is applicable.

Step 2 - If no knock occurs, go to a lower octane number blend in that series and repeat Step 1.

Step 3 - If knock occurs at one or more of the operating conditions in Step 1, continue investigation at the critical condition(s) with higher octane blends until highest octane fuel giving knock is determined within one octane number or one blend (the next higher fuel giving no knock). Record maximum knock intensity on all fuels. Record speed of maximum knock intensity and manifold vacuum/pressure on highest octane fuel that knocks.

Step 4 - Using the lowest octane blend that did not knock in Step 3, investigate for incidence of part-throttle knock as described in D.3.d.(1)(d). If knock occurs, continue investigation at critical vacuum/pressure until requirement is defined. Record maximum knock intensity and critical manifold vacuum/pressure on all fuels, and speed of maximum knock intensity on highest octane fuel that knocks.

Step 5 - With FBRU fuel only, if no knock occurs in Step 4, go to a lower octane number blend and repeat Step 4. Discontinue part-throttle investigation if knock is not observed with a fuel four octane numbers lower than determined in Step 3.

Step 6 - For knock-sensor equipped vehicles after determination of maximum requirement, continue with lower octane blends until the lowest octane fuel giving borderline knock is determined (the next lowest fuel giving above borderline knock).

The rating procedure is given in arrow diagram form on page B-13 for maximum requirement, and on page B-14 for minimum requirement, for knock sensor-equipped cars.

E. INTERPRETATION OF DATA

The data will be recorded on data sheets DFMF-11-87 and DFMF-19-87. *Data Form DFMF-11-87 has provisions for recording both the maximum and minimum requirements of knock-sensor equipped vehicles on the same sheet. Additional data sheets for recording run data may be appended to DFMF-11-87 as needed.* Octane requirements for all reference fuels shall be determined as follows:

1. If the knock intensity of the highest reference fuel giving knock is borderline, the requirement shall be reported as the octane number of that fuel.

2. If the knock intensity of the highest fuel giving knock is above borderline, the requirement shall be reported as the mid-point between the octane number of the fuel giving knock and that of the next higher fuel.

3. If the octane requirement in high gear is equal to the requirement in a lower gear, report the highest gear data.

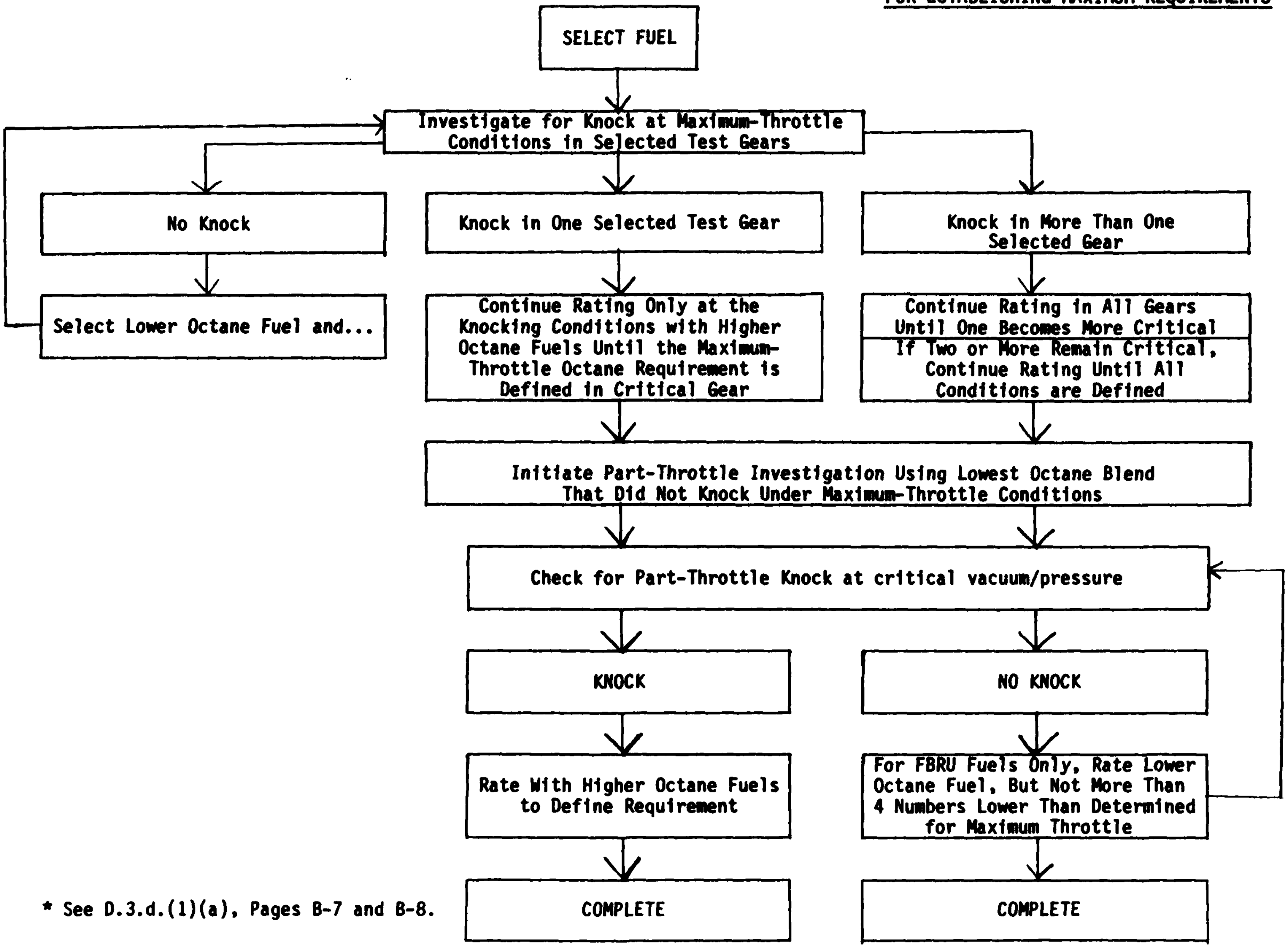
4. For part-throttle requirements, report the data from the critical manifold vacuum/pressure observations.

5. For knock-sensor equipped vehicles, report the highest and lowest fuel giving borderline knock. If the knock intensity with the lowest fuel giving knock is above borderline and the next highest fuel is no knock, then the minimum requirement is the mid-point between the two.

Record data on all fuels tested, even though knock was not encountered. *The octane number requirement summary block on the first sheet of DFMF-11-87 provides space for both the maximum and the minimum requirements of knock-sensor equipped vehicles.* When transferring data to the summary block, record maximum-throttle and part-throttle octane number requirements in the appropriate blocks. The higher of the two will be selected by the computer as the maximum octane number requirement. If both maximum-throttle and part-throttle requirements are equal, then the computer will select the part-throttle requirement as the maximum octane number requirement. Use proper letter designation (see footnotes on data sheet) to designate: (1)requirements outside of the reference fuel limits; (2) FBRU part-throttle requirement more than four numbers below maximum; *and (3) all other cases for which the octane number requirement has not been determined. Note that in the case of a converter-clutch equipped vehicle, test gear numbers should indicate whether the converter clutch was locked or unlocked. Note also that in the case of turbo-equipped vehicles, a manifold pressure above atmospheric is indicated as a* negative *number in units of psig.*

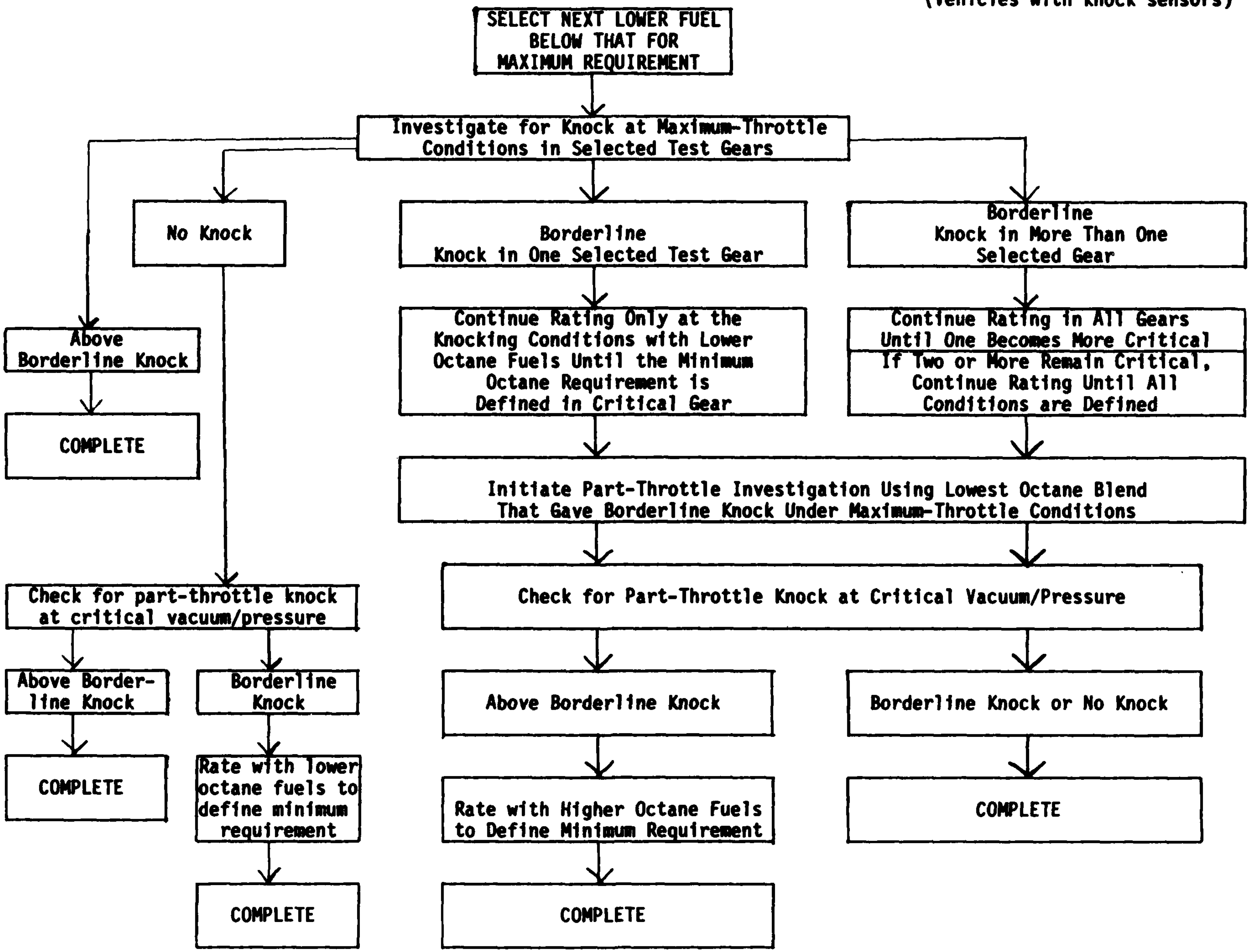
It is important that the vehicle identification number (VIN) of each vehicle tested be recorded on all data sheets to provide a means of cross-indexing.

FOR ESTABLISHING MAXIMUM REQUIREMENTS



* See D.3.d.(1)(a), Pages B-7 and B-8.

FOR ESTABLISHING MINIMUM REQUIREMENTS
(Vehicles with knock sensors)



* See D.3.d.(1)(a), Pages B-7 and B-8.

ANNEX A

to the

CRC E-15-87 TECHNIQUE

PROCEDURE FOR SETTING UP VEHICLES

WITH FUEL INJECTION

ANNEX A

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS: VEHICLES EQUIPPED WITH FUEL INJECTION

1. To run octane requirements on fuel-injected vehicles, it is necessary to install an external fuel supply line with auxiliary electric fuel pump from the reference fuel can to the vehicle fuel system and an external return line back to the reference fuel can.

2. There are two types of fuel injection systems: throttle-body injection, and multi-port injection. As a general description, the systems will contain the following parts:

   Fuel Tank
   High- or Low-Pressure In-Tank Fuel Pump
   Fuel Supply Line(s)
   In-Line Filter(s)
   High-Pressure Chassis-Mounted Pump (not required for all vehicles)
   Fuel Rail (to supply multiple injectors on port fuel injection)
   Fuel-Pressure Regulator (integral on throttle-body, on fuel rail with multi-port injection; controls pressure at the injectors).

   Depending upon the vehicle's specific fuel system and/or tester's preference, installation of the required auxiliary equipment can be accomplished in a variety of ways.

3. The auxiliary fuel supply line may be installed anywhere between the fuel tank and the inlet at the throttle-body or fuel rail. The auxiliary fuel return line may be installed anywhere between the fuel-pressure regulator outlet and the tank.

4. After connections have been broken, the fuel lines on the fuel tank side should be capped and the vehicle's pump(s) disconnected or disarmed. Alternately, an additional fuel line can be looped between the supply and return lines and the vehicle pump(s) allowed to circulate fuel directly back to the fuel tank. Caution should be exercised if this alternate technique is used. A high pressure will build up in the tank due to the large amount of vapors generated.

   The auxiliary fuel supply system must be capable of supplying fuel at a pressure slightly higher than the maximum fuel pressure required (at wide-open-throttle on normally aspirated engines or at maximum manifold boost pressure on turbocharged or supercharged engines) by the particular vehicle being tested. This is to overcome any line losses and thus insure accurate results. This may be accomplished by using an adjustable high-pressure pump, or by using a low-pressure pump to supply fuel to the chassis-mounted high-pressure pump if the testing

lab chooses to keep it in the system. A fuel filter may be required between the auxiliary pump and the reference fuel can to protect the pump. The fuel return line should be connected to a tee at the auxiliary pump inlet. The reference fuel can should be vented to outside the vehicle.

It is possible to use three-way valves in the fuel line between the fuel pump and the fuel tank and between the return line and the fuel tank. When used, the operator must change the return line valve to the auxiliary fuel system while the engine is shut down, to avoid building up excessive pressure in the return line which could damage both the fuel-pressure regulator and injection pump.

5. When changing from one reference fuel can to another, the following steps should be followed:

   a. Disconnect fuel inlet line from reference fuel can and run engine a short time; do not run out of fuel since this will introduce air into the fuel injection system and excessive cranking will be required to restart the engine.

   b. With the engine shut off, disconnect the fuel return line from the auxiliary pump inlet and connect it to a slop can. Connect the fuel supply line to the new reference fuel can and run the engine long enough to purge the old reference fuel from the system. The time required will be dependent upon length of added fuel lines, but it will be approximately 30-60 seconds[1]; approximately 1-2 quarts of fuel will be discarded to slop.

   c. With the engine off, connect the fuel return line to the auxiliary pump inlet. The vehicle is then ready to be tested.

   d. When changing to the next reference fuel, it is necessary to repeat Steps a, b, and c.

CAUTION

Fuel supply lines remain pressurized long after the engine is shut off; be sure to relieve the pressure before disconnecting fuel lines.

Use fuel lines designed for high pressure. They should be rated for at least 250 psi working pressure and for 1000 psi burst pressure.

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(1) It is critical to circulate an adequate amount of fuel to the slop can to prevent reference fuel contamination.

CAUTION - (Continued)

The engine and auxiliary fuel pumps should be shut off while changing from auxiliary to tank fuels.

Purging procedures should be followed strictly to preclude reference fuel contamination or discarding more fuel than is required.

Vehicle pump(s) may be disarmed by use of the inertia switch if so equipped. The voltage supplied to the inertia switch may then be used to power the auxiliary pump. When making these electrical connections, do not "splice" into the wire; instead, connect the wire lead to the connector.

Do not disarm the vehicle fuel pump by removing the fuse, since other accessories may be connected to the same circuit; instead, disconnect the fuel pump electrical lead.

Auxiliary fuel return lines should be of a size large enough to prevent a build-up of back pressure which could prevent the proper operation of the pressure regulator.

Use of the "rolled edge" style hose clamps, such as those made by Chrysler, is recommended to prevent damage to fuel lines.

Note: Diagnostic scanners should not be used while knock testing.

APPENDIX C

REVISED

CRC OCTANE NUMBER REQUIREMENT RATING FORM DFMF-11-87

DFMF-11-87 Sheet____of____Sheets

1987 CRC OCTANE NUMBER REQUIREMENT SURVEY - 1987 MODEL VEHICLES

Company:____________________ Date:____________ Test Location (R/C):________________ (1)*

Primary Contact:________________________________ Phone: ( )__________

Driver:________________________ Observer:____________________________

TO BE FILLED IN BY CRC: Observation No.:_____-_____ Vehicle Code:__________ VIN Digit:__________

VEHICLE DATA

Vehicle Make:____________________ Model:________________________

Engine Type:________(2)* V.I.N.: !_!_!_!_!_!_!_!_!_!_!_!_!_!_!_!_!_!

Engine Calibration (Ford):______________ License No.:____________________

Knock Sensor (Y/N):______ Emission Certification (F/C/A/B/E):________(3)

Induction (V/T): ______(4) Carburetion (P/T/1..4):____________(5)

Displacement (Liters): _____._____ Compression Ratio:_____._____

Transmission (A/M):______(6) No. of Speeds:______(7) Converter Clutch (Y/N):________

Spark Advance (Degrees BTDC)(8):______ As Received:__________ As Tested:__________

Air Conditioning (Y/N):______ Odometer (Miles):____________________

WEATHER Ambient Temperature (°F):______ Barometer ("Hg):____.____ Humidity (Gr/Lb):________

TANK FUEL DATA

Customer Knock (Y/N/O):________(9) Research Octane No.:_____.__ Motor Octane No. _____.__

Knock Intensity (N/B/A):________(10) Throttle (M/P):_______(11) Test Gear No.:________________(12)

RPM @ Max. Knock Intensity:________ Man. Vac. ("Hg/psig):____.___(13)

OCTANE NUMBER REQUIREMENTS

Ref Test Fuel	MAXIMUM REQUIREMENTS				MINUMUM REQUIREMENTS (14)			
	Research Oct. No. (15)	Test Gear (12)	RPM @ Max. Knock	Manifold Vacuum ("Hg/psig) (13)	Research Oct. No. (15)	Test Gear (12)	RPM @ Max Knock	Manifold Vacuum ("Hg/psig) (13)
	Maximum-Throttle Requirement							
FBRSU	___.__	___	___	___.__	___.__	___	___	___.__
FBRU	___.__	___	___	___.__	___.__	___	___	___.__
PR	___.__	___	___	___.__	___.__	___	___	___.__
	Part-throttle Requirement							
FBRSU	___.__	___	___	___.__	___.__	___	___	___.__
FBRU	___.__	___	___	___.__	___.__	___	___	___.__
PR	___.__	___	___	___.__	___.__	___	___	___.__

* See last page for explanatory Legend.

TRANSMISSION DOWNSHIFT CHARACTERISTICS

4th Locked Overdrive			4th Gear			3rd Locked		
mph	Man. Vac./psig	RPM	mph	Man. Vac./psig	RPM	mph	Man. Vac./psig	RPM
*			*			*		

3rd Gear			2nd Locked			2nd Gear		
mph	Man. Vac./psig	RPM	mph	Man. Vac./psig	RPM	mph	Man. Vac./psig	RPM
*			*			*		

Minimum Road Speed Attainable in each Gear/Converter Clutch Combination at _______ Man. Vac./psig (light throttle)		
mph	Gear/Converter Clutch	RPM

(To obtain critical part-throttle vacuum/pressure)

ROAD LOAD		
mph	Man. Vac./psig	Gear

(For initial accelerations)

ROAD LOAD		
mph	Man. Vac./psig	Gear
15		
25		
35		
45		
55		

* Indicate speed at which gear or gear/converter clutch first engages.

DFMF-11-87

Sheet____of____Sheeets

1987 CRC OCTANE NUMBER REQUIREMENT SURVEY - 1987 MODEL VEHICLES
CONTINUATION SHEET

Company:______________________________ Date:______________________________

Vehicle Make:______________________________ Model:______________________________

V.I.N.:______________________________ License No.:______________________________

TO BE FILLED IN BY CRC: Observation No.:____-____

Reference Fuel		Test Gear No. (12)	Man. Vac. "Hg/psig (13)	Max. Knock Intensity (10)			(10)	Speed Range, RPM		RPM of Max. Knock Intensity
				Acceleration						
Series	Res. O.N.			1	2	3	Final Rating	Knock In	Knock Out	

Reference Fuel		Test Gear No. (12)	Man. Vac. "Hg/psig (13)	Max. Knock Intensity (10)			(10)	Speed Range, RPM		RPM of Max. Knock Intensity
				Acceleration						
Series	Res. O.N.			1	2	3	Final Rating	Knock In	Knock Out	

LEGEND

(1) R = Road; C = Chassis Dynamometer
(2) e.g. V8, L4, R for Rotary
(3) F = Federal; C = California;
A = Altitude; B = "C" and "A"
E = Everything
(4) V = Variable Venturi;
T = Turbocharged
(5) Number of Carb. Venturis or T for throttle body injection or P for port injection
(6) A = Automatic; M = Manual
(7) Record number of transmission speeds
(8) + = BTDC; - = ATDC
(9) Y = Yes; N = No; O = Objectionable
(10) N = None; B = Borderline
A = Above Borderline
(11) M = Maximum-Throttle;
P = Part-Throttle higher than Maximum-Throttle Requirement
(12) If vehicle is equipped with converter clutch, in addition to gear number, indicate U for unlocked and L for locked (e.g., 3U)
(13) If boost pressure greater than atmospheric, use Manifold Pressure (psig) with minus sign (-)
(14) Applies only to knock-sensor vehicles.
(15) If ONR not bounded by test fuels,
L = Less than lowest available fuel;
H = Higher than highest available fuel.
If part-throttle requirement is greater than four numbers below maximum-throttle requirement, enter F.
If above does not apply and ONR is not determined, enter U.

COMMENTS